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IS 12316-2 (1988): Non-cellulosic papers for electrical purposes, Part 2: Methods of test [ETD 2: Solid Electrical Insulating Materials and Insulation Systems]



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*Indian Standard*

**SPECIFICATION FOR  
NON-CELLULOSIC PAPERS FOR  
ELECTRICAL PURPOSES**

**PART 2 METHODS OF TEST**

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**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

# Indian Standard

## SPECIFICATION FOR NON-CELLULOSIC PAPERS FOR ELECTRICAL PURPOSES

### PART 2 METHODS OF TEST

#### 0. FOREWORD

**0.1** This Indian Standard ( Part 2 ) was adopted by the Bureau of Indian Standards on 2 March 1988, after the draft finalized by the Solid Electrical Insulating Materials Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** This Indian Standard ( Part 2 ) is one of the series of Indian Standards which deals with non-cellulosic papers for electrical purposes. This series will have the following three parts:

- Part 1 Definitions and general requirements,
- Part 2 Methods of test, and
- Part 3 Specifications for individual materials.

**0.3** This standard ( Part 2 ) covers the methods of test for non-cellulosic papers for electrical purposes.

**0.4** Cellulosic papers are covered in IS : 9335\*.

**0.5** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

\*Specification for cellulosic papers for electrical purposes.

†Rules for rounding off numerical values ( revised ).

#### 1. SCOPE

**1.1** This standard ( Part 2 ) covers the methods of test applicable to non-cellulosic papers for electrical purposes.

**1.2** For general tests that are not covered in this standard, reference may be made to IS : 1060 ( Part 1 )-1966\*, IS : 1060 ( Part 2 )-1960† and IS : 1060 ( Part 3 )-1969‡.

#### 2. GENERAL NOTES ON TESTS

**2.1** In this standard, reference is made at several places to a particular Indian Standard accompanied by a short description of the method used. It is to be understood that this short description is meant for identification purposes only and that all details shall be taken from the relevant Indian Standard.

**2.2** In this standard, the following definitions of 'specimen' and 'test piece' shall be used as are defined in IS : 1060 ( Part 1 )-1966\*.

**Specimen** — A rectangle of paper or board cut to given dimensions from sheets drawn from selected units.

\*Methods of sampling and test for paper and allied products : Part 1 ( revised ).

†Methods of sampling and test for paper and allied products : Part 2.

‡Methods of sampling and test for paper and allied products : Part 3.

**Test Piece** — The quantity of paper or board on which the determination is carried out in accordance with the method of test. It may be taken from a specimen; in some instances it may be the specimen itself.

**2.3** Unless specified otherwise, the specimen, after being cut, shall be conditioned for not less than 16 h in an atmosphere of  $27 \pm 2^\circ\text{C}$  and  $65 \pm 2$  percent relative humidity. Test pieces are cut from the specimen and tested in this atmosphere.

In case of dispute, the conditioning atmosphere shall be  $27 \pm 1^\circ\text{C}$  and  $65 \pm 2$  percent relative humidity and shall be approached from the dry side (after drying at  $70^\circ\text{C}$  to a moisture content less than 4 percent).

**2.4** Unless specified otherwise, the number of specimen shall be three.

#### 3. THICKNESS

**3.0** Thickness shall be measured in accordance with IS : 1060 ( Part 1 )-1966\* by either of the following methods.

##### 3.1 Determination of the Thickness of Single Sheets of Paper

**3.1.1 Principle** — The method is based on the use of a precision dial micrometer to measure the thickness of a single sheet when a static load is applied.

\*Methods of sampling and test for paper and allied products : Part 1 ( revised ).

**3.1.2 Exceptions** — The test shall be carried out on three conditioned test pieces, one determination being made on each of the three test pieces.

Reporting of the standard deviation is optional.

The central value is taken as the result; the two others are reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3 of this standard.

### 3.2 Method for the Determination of the Bulking Thickness and Bulk of Paper

**3.2.1 Principle** — The method is based on the use of a precision dial micrometer to measure the thickness of a stack composed of a minimum of five sheets.

**3.2.2 Exceptions** — The test shall be carried out on three conditioned specimens, each composed of five sheets.

For narrow width material where the width is less than the stipulated 250 mm, the five measurements on each stack shall be made at approximately equal intervals on a specimen 400 mm in length.

The central value is taken as the result, the two others being reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3 of this standard.

### 4. SUBSTANCE (MASS/m<sup>2</sup>, BASIC WEIGHT OR GRAMMAGE)

**4.1** Paper grammage shall be measured according to the methods described in IS : 1060 (Part 1)-1966\* with the following exceptions:

- a) The test shall be carried out on three conditioned test pieces, one determination being made on each of the three test pieces;
- b) The mass is to be determined to an accuracy of 0.5 percent on conditioned test pieces of not less than 500 cm<sup>2</sup>; and
- c) The central value is taken as the result, the two others being reported.

**4.2 Principle** — The area of each test piece and its mass are measured and the mass/m<sup>2</sup> is calculated, all measurements being made on conditioned test piece.

Where grammage is determined across the width to establish the variation over the width,

\*Methods of sampling and test for paper and allied products: Part 1 (revised).

the details of this procedure will be found in Part 3 of this standard.

### 5. APPARENT DENSITY

**5.1** The thickness and grammage are determined on each of three test pieces in accordance with 3 and 4. For each test piece, the apparent density is calculated and the average value of these three densities taken as the result; the two others are reported. The apparent density is expressed in g/cm<sup>3</sup>.

### 6. TENSILE STRENGTH AND ELONGATION

**6.1** Tensile strength and elongation shall be measured according to the method described in IS : 1060 (Part 1)-1966\* with the following exceptions:

- a) Nine measurements are made on test pieces cut from both the machine direction and cross direction;
- b) The central value of the test pieces in each direction is taken as the result and the highest and the lowest values in each direction are reported; and
- c) Alternatively, the results can be expressed as breaking length in metres to the nearest 100 m.

**6.2 Principle** — Measurement of the tensile force required to cause failure of test pieces 15 mm × 250 mm approximately, cut from directions of the paper, when applied under standard test conditions.

### 7. INTERNAL TEARING RESISTANCE

**7.1** Internal tearing resistance shall be measured according to the method described in IS : 1060 (Part 1)-1966\*. The single tear tester shall be used with the following exceptions:

- a) Nine measurements are made on test pieces cut from both the machine direction and the cross direction; and
- b) The central value of the test pieces, in each direction, is taken as the result and the highest and the lowest values in each direction are reported.

**7.2 Principle** — Rectangular test pieces having a single cut leaving 43 mm length to be torn and measuring the energy required to tear this.

### 8. EDGE TEARING RESISTANCE

#### 8.1 Test Apparatus

**8.1.1** An edge tear stirrup [see Fig. 1 of IS : 9335 (Part 2)-1981†] shall be used,

\*Methods of sampling and test for paper and allied products: Part 1 (revised).

†Specification for cellulosic papers for electrical purposes: Part 2 Methods of test.

attached to the tensile testing apparatus as described in 6. The edge tear stirrup consists of a thin steel plate (A) which form a horizontal plate supported on edge by the ends of a stirrup-shaped frame.

**8.1.2** The thin metal tang of the stirrup frame is fastened in the lower clamp of the tension testing machines so that the vertical centre line of the stirrup coincides with the line connecting the midpoints of the upper and lower clamps. The horizontal plate is removable from the stirrup frame and two plates of different thicknesses are supplied for use with papers of different thickness ranges. One plate has a thickness of  $1.25 \pm 0.05$  mm and the other one of  $2.50 \pm 0.05$  mm. The edge of the plate forms a shallow V-notch, the sides of which subtend an angle of  $150 \pm 1^\circ$ . The sides of the V-notch are semicircular in cross-section and shall be smooth and straight.

**8.2 Test Pieces** — Nine test pieces shall be cut in the machine direction and nine in the cross direction of the paper, 15 to 25 mm in width and not less than 250 mm in length.

The test pieces shall be conditioned according to 2.3.

**8.3 Procedure** — Attach a plate of the proper thickness to the stirrup frame. The plate with the thickness of  $1.25 \pm 0.05$  mm is to be used for papers of up to 0.75 mm thickness and the plate with the thickness of  $2.50 \pm 0.05$  mm for thicker papers.

Fasten the thin tang of the stirrup in the lower clamp (see Note) of the tension-testing machine so that the vertical centre line of the stirrup coincides with the line connecting the midpoints of the upper and lower clamps of the testing machine, and the sides of the V-notch are symmetrically located with the line through the midpoints of the clamps.

**NOTE** — The stirrup may be fastened in the upper clamp, if desired. This procedure will require rebalancing the tension-testing machine to compensate for the mass of the stirrup.

Place the lower clamp of the machine in such a manner that the lower edge of the upper clamp is about 90 mm above the V-notched plate.

Thread the test piece through the stirrup, under the plate, bring the two ends together and fasten them in the upper clamp.

In this operation, most of the slack in the test piece is taken up, but care shall be exercised not to apply a tearing force to the test piece. Make the application of the first increments of load to the test piece very slowly, if possible, to minimize abnormal strains due to inertia effects. Increase the load so that tearing starts in 5 to 15 s and record this load in kilograms.

**8.4 Results** — Report the central values for each of the two directions of the paper in newtons mentioning the thickness of the plate used, the

rate of loading, and the width and thickness of the test pieces.

## 9. BURSTING STRENGTH

**9.1** The bursting strength shall be determined according to the method described in IS : 1060 (Part 1)-1966\* with the following exceptions:

- The test pieces shall be conditioned in accordance with 2.3; and
- The central value shall be taken as the result, the highest and lowest values shall be reported.

**9.2 Principle** — A test piece, placed in contact with a circular elastic diaphragm, is rigidly clamped at the periphery but free to bulge with the diaphragm. Hydraulic fluid is pumped at a constant rate, bulging the diaphragm until the test piece ruptures. The bursting strength of the test piece is the maximum value of the applied hydraulic pressure.

## 10. ELECTRIC STRENGTH

**10.0** The test shall be carried out in air in accordance with IS : 2584-1963†.

**10.1 Test Apparatus** — The apparatus and electrodes shall be in accordance with IS : 2584-1963†. The preferred electrodes are the 25/75 mm electrodes. The smaller electrodes shall be used only if the width of the material prevents the use of the large electrodes. The faces of the electrodes shall be parallel and free from pits or other imperfections.

**10.2 Test Pieces** — All test pieces shall be sufficiently large to avoid flashover.

The required number of tests be made on one test piece. Where more than one thickness are required to form the test piece, the number of super-imposed layers shall be as given in Part 3 of this standard.

Where the temperature or humidity of the test differ from those of 2.3, the treatment of the test piece shall be as given in Part 3 of this standard.

**10.3 Procedure** — The application of voltage and criterion of breakdown shall be in accordance with IS : 2584 - 1963†.

Nine tests shall be made.

**10.4 Results** — The result shall be based on the measured thickness. The report shall be in accordance with IS : 2584 - 1963†. The central value and the lowest value shall be reported in kV/mm.

**NOTE** — For special papers, a more elaborate statistical evaluation may be required. Test method shall be as given in Part 3 of this standard.

\*Methods of sampling and test for paper and allied products : Part 1 ( revised ).

†Method of test for electric strength of solid insulating materials at power frequencies.

## 10.5 Electric Strength of Paper Using Direct Current

### 10.5.1 Test Apparatus

**10.5.1.1 Voltage source** — The voltage source shall be capable of supplying a voltage continuously variable from 40 percent of typical breakdown values to 120 percent of maximum breakdown value at an ac ripple of less than 2 percent of the peak output voltage at any achievable voltage and when supplying a current of 1 mA. This source shall be equipped with a device which automatically disconnects the source from the sample, should the current rise to a pre-set value of  $0.1 \text{ mA} \pm 0.001 \text{ mA}$  within a maximum time of 0.1 second. The voltage measuring device shall follow the rising voltage at the maximum of rate of rise required so that at no time is the indicated voltage less than 99 percent of the actual value.

**10.5.2 Electrodes** — Two cylindrical electrodes made from stainless steel (with a surface fineness of  $2.5 \mu\text{m}$  or better) shall be used. The faces of electrodes shall be parallel and free from pits of other impurities. The edges shall be removed to give a radius of 3.0 mm.

The upper electrode shall have diameter of 25 mm and a height of approximately 25 mm. The counter electrode beneath shall have 75 mm diameter and a height of approximately 15 mm and should be arranged coaxially in accordance with 5.1.1 and Fig. 1A of IS : 2584-1963\*.

The counter electrode connected with earth potential may also consist of a plane sheet of 40 - 50  $\mu\text{m}$  thick aluminium foil (capacitor foil with the glossy surface facing the upper electrode), which shall be free from greases and shall conform to the underlying supporting surface which shall be smooth and plane as well.

### 10.5.3 Air Circulating Oven

**10.5.4 Test Pieces** — The test pieces shall be large enough to prevent flashovers. Two layers of paper, one upon the other, are measured except when otherwise specified in Part 3 of this standard.

The test pieces shall be cut from one specimen. For example, a sheet of  $40 \times 40 \text{ cm}$  is taken from the paper and cut to two double-layered test pieces of  $20 \times 20 \text{ cm}$ .

**10.5.5 Procedure** — The test pieces shall be suspended or piled loosely in not more than 20 layers in an air circulating oven and shall be dried there at  $105 \pm 2^\circ\text{C}$  for 60 minutes and

tested within 1 minute of removal from the oven. In case of dispute, the test shall be carried out inside the oven.

**10.5.6 Number of Measurements** — A minimum of nine measurements (breakdown) shall be carried out. When the lower 95 percent confidence limit on the test result is required, 20 breakdowns or more shall be made. The lag of the measuring instrument shall not exceed 1 percent.

**10.5.7 Measuring Procedure** — The voltage shall be increased from about one half of the expected breakdown voltage to breakdown in 5 to 10 seconds. The approximate breakdown value is found by two previous tests.

For paper with nominal thickness of  $\leq 25 \mu\text{m}$ , the voltage is increased by 200 to 300 V per second until breakdown. At breakdown that is, when the short-circuit current has reached 0.1 to 1.0 mA, the volt meter shall continue to indicate the breakdown voltage.

NOTE — The limitation of the short-circuit current is arrived by a protective resistor put in series with the specimen. The short-circuit current is limited to 0.1 to 1.0 mA in order to avoid damage of the electrodes.

### 10.5.8 Results

**10.5.8.1** The report shall include the following:

- Average thickness of the double layer paper;
- Type and size of electrodes;
- Number of breakdown;
- Minimum value, maximum value, central value;
- Electric strength ( $\text{mV/m} = \text{kV/mm}$ ) calculated from the central value divided by the thickness of double-layered paper; and
- In case the lower 95 percent confidence limit is required, ( $\geq 20$  measurements).

$\bar{X}$  = mean value

SD = simple standard deviation

$I_{LC}$  = lower confidence limit

$= \bar{X} - (SD 1.64)$

## 11. SHRINKAGE ON HEATING

**11.1** Three test pieces  $250 \times 250 \text{ mm}$  to be heated in an oven at  $300 \pm 5^\circ\text{C}$  for 40 to 45 minutes. Pieces to be suspended vertically with clamps or light weights on bottom edge to prevent curling during heating. Condition in accordance with 2.3 before and after heating and make measurements on conditioned pieces. Report the control values.

\*Method of test for electric strength of solid insulating materials at power frequencies.

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